

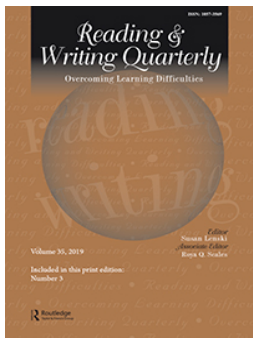
PDF hosted at the Radboud Repository of the Radboud University Nijmegen

The following full text is a publisher's version.

For additional information about this publication click this link.

<http://hdl.handle.net/2066/203623>

Please be advised that this information was generated on 2020-09-10 and may be subject to change.



Reading & Writing Quarterly

Overcoming Learning Difficulties

ISSN: 1057-3569 (Print) 1521-0693 (Online) Journal homepage: <https://www.tandfonline.com/loi/urwl20>

The Efficiency of Briefly Presenting Word Forms in a Computerized Repeated Spelling Training

Sophie Gruhn, Eliane Segers & Ludo Verhoeven

To cite this article: Sophie Gruhn, Eliane Segers & Ludo Verhoeven (2019) The Efficiency of Briefly Presenting Word Forms in a Computerized Repeated Spelling Training, *Reading & Writing Quarterly*, 35:3, 225-242, DOI: [10.1080/10573569.2018.1526725](https://doi.org/10.1080/10573569.2018.1526725)

To link to this article: <https://doi.org/10.1080/10573569.2018.1526725>



© 2019 The Author(s). Published with license by Taylor & Francis Group, LLC



Published online: 07 Jan 2019.



Submit your article to this journal [↗](#)



Article views: 736



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 1 View citing articles [↗](#)

The Efficiency of Briefly Presenting Word Forms in a Computerized Repeated Spelling Training

Sophie Gruhn^a, Eliane Segers^{a,b}, and Ludo Verhoeven^{a,c}



^aRadboud University, Nijmegen, The Netherlands; ^bUniversity of Twente, Enschede, The Netherlands;


^cUniversity of Curaçao, Curaçao, The Netherlands

ABSTRACT

We investigated the efficiency of briefly presenting word forms (visual dictation) over and above word copying in 5 computerized repeated spelling training sessions of Dutch rule-based and loan words in advanced spellers in primary school. Using repeated measures analyses of variance, we compared the effects of 2 spelling feedback conditions in a between-subjects pretest/posttest control group design on growth in spelling accuracy and speed for trained and comparable untrained words. Children in the visual dictation condition ($n = 29$) had to spell a word from memory after briefly seeing the correct form, whereas children in the word copying condition ($n = 30$) just had to copy the correct form. In an additional control condition ($n = 31$), children only received feedback on correctness. We assessed improvement in the reading of trained words and in the reading and spelling of comparable untrained words via pre- and posttest. By the end of the training, children in the visual dictation condition outperformed the control group on spelling accuracy of both rule-based words and loan words (both $ps < .001$), whereas the word copying group only did so for loan words ($p < .001$). In contrast to the control group, the word copying group caught up with the visual dictation group on both word types; however, children in the visual dictation group attained higher spelling accuracy earlier during training. We found no differential transfer effects. We can thus conclude that visual dictation was the most efficient way of memorizing spelling representations of both rule-based words and loan words.

Proficiency in spelling is highly relevant for children's future academic success because it allows a focus on text composition and the perceptive quality of written text is downgraded by spelling errors (Abbott, Berninger, & Fayol, 2010; Johnson, Wilson, & Roscoe, 2017). Spelling is more difficult than reading, and many children struggle at becoming proficient in spelling (Arndt & Foorman, 2010; Conrad, 2008; Martin-Chang, Quelette, & Madden, 2014). The spellings of some words can be learned via spelling rules; other, irregularly spelled words, such as words borrowed from other languages (loan words), often have to be memorized (Apel, 2011; Ehri, 2017; Sankoff, 2006). This memorization of lexical knowledge is based on repetition until the correct spelling is sufficiently stored in memory (Hilte & Reitsma, 2011b; Ouellette, 2010; Shahar-Yames & Share, 2008). Often this is achieved by repeated reading of words, but it has been shown that repeated copying is more efficient (Bhide, 2018; Bosman & Van Leerdam, 1993; Pan, Rubin, & Rickard,

CONTACT Sophie Gruhn  c.gruhn@bsi.ru.nl  Behavioural Science Institute, Radboud University, Postbus 9104, 6500 HE Nijmegen, The Netherlands.

 Supplemental data for this article can be accessed on the [publisher's website](#).

© 2019 The Author(s). Published with license by Taylor & Francis Group, LLC

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

2015). Even more efficient than copying is spelling words from memory after briefly previewing the correct form (visual dictation; e.g., Bosman, Van Huygevoort, & Verhoeven, 2006; Cates et al., 2007; Gaintza & Goikoetxea, 2016; Hilte & Reitsma, 2006, 2008; Nies & Belfiore, 2006; Van Leerdam, Bosman, & Van Orden, 1998). However, a direct comparison of copying versus retrieving words from memory has not been made for rule-based words versus loan words, and the efficiency of the methods may differ for these two word types. Also, the transfer effects of a spelling training with visual dictation to reading the trained words and to reading and spelling similar untrained words have not been investigated. In the present study, we thus compared direct training and transfer effects of Dutch rule-based words and loan words in a repeated spelling intervention with a visual dictation condition versus a word copying condition and a control condition with only feedback on correctness.

Learning to spell

Learning to spell starts with the ability to segment words into syllables and phonemes and to represent each phoneme by a grapheme (Ehri, 2017). With practice, this process becomes more automatized and word forms are represented in a mental lexicon, which allows to access whole word units. Thus, children make steps from segmental toward lexical spelling of words. Different spelling strategies are used in parallel throughout development depending on children's competence and experience (Critten, Sheriston, & Mann, 2016; Sharp, Sinatra, & Reynolds, 2008). According to the lexical quality hypothesis, one can learn words by storing an orthographic, phonological, and semantic representation in memory (Martin-Chang et al., 2014; Perfetti, 1992, 2017). The quality of the representation depends on the strength of each informational node and also on the strength of the link between them. Over time, the quality of the lexical representation improves steadily in terms of rising specificity and redundancy. Representations in which each phoneme and grapheme are fully specified are more precise and stable, which leads to higher accuracy in reading and spelling. In more specified representations, the redundancy of the stored information increases because the orthographic and phonological information gets bonded so closely that they are inherent to each other, which fosters quick lexical access. Accuracy and speed in reading and spelling therefore may allow conclusions to be drawn about the underlying quality of the lexical representations.

Spelling development is related to the consistency with which phonemes are presented by graphemes in a certain language (Caravolas, 2006; Marinelli, Romani, Burani, & Zoccolotti, 2015). Children first acquire alphabetical knowledge, but in most languages they also learn spelling rules and have to store mental representations of exceptions (Apel, 2011; Joshi & Aaron, 2006). For example in Dutch in particular, rule-based spelling and the spelling of loan words generally cause problems until the end of primary education (Bosman, De Graff, & Gijssels, 2006; Keuning & Verhoeven, 2008; Nunn, 1998). Children get help from rules to memorize the spellings of rule-based words. These rules do not apply to loan words, which require full memory retrieval because they are derived from the typical spelling conventions in a language. For learning to spell loan words, the conscious application of a memorization strategy might be useful, such as reading irregularly spelled words in a regularized manner (i.e., reading with a consistent grapheme–phoneme convergence; Bosman, Van Hell, & Verhoeven, 2006; Elbro & De Jong, 2017; Hilte & Reitsma, 2006). In contrast, the conscious application of spelling rules is usually necessary for spelling rule-based words, which becomes more and more automatized. Spelling loan words is often introduced at a later stage of spelling instruction and is considered to be more difficult than spelling rule-based words (Arndt & Foorman, 2010; Keuning & Verhoeven, 2008).

Generally speaking, repetition is a useful and natural learning tool in reading practice (Berends & Reitsma, 2006; Huemer, Aro, Landerl, & Lyytinen, 2010; Levy, 2001; Thaler, Ebner, Wimmer, & Landerl, 2004; Van Gorp, Sergers, & Verhoeven, 2017) because of an assumed self-teaching

mechanism in which lexical learning is fostered by repeated phonological decoding (Bosse, Chaves, Largy, & Valdois, 2015; Share, 1995, 2004). Although this self-teaching mechanism was introduced initially for repeated reading practice, spelling practice similarly leads to strengthening of lexical representations by means of repeated regular mappings between phonemes and graphemes (Perfetti, 2017; Ouellette, 2010; Shahar-Yames & Share, 2008). Repetition has also been shown to be efficient for learning irregular word spellings (e.g., Bosman, Van Huygevoort et al., 2006; Gaintza & Goikoetxea, 2016). Although spelling rules are naturally taught by explicit explanation, simple repetition can also teach spelling rules. Second graders who repeatedly spelled rule-based words without explicit teaching of rules had similar improvements in accuracy to a group that practiced with explicit teaching of rules and also showed transfer to untrained words (Hilte & Reitsma, 2011b).

Besides explicit teaching of spelling rules, sensitivity to the statistical properties of a language can also lead to implicit abstraction of rules for certain spelling conventions (Deacon, Conrad, & Pacton, 2008; Kemp & Bryant, 2003; Steffler, 2001). For transfer to untrained loan words, children can make use of analogy by applying already existing lexical knowledge in order to spell unfamiliar words correctly, such as spelling *panic* based on *manic* (Bosse, Valdois, & Tainturier, 2003; Tucker, Castles, Laroche, & Deacon, 2016).

Repeated spelling training

Repeated spelling training of rule-based words and loan words contributes to the construction of highly specified lexical representations (Perfetti, 1992, 2017; Shahar-Yames & Share, 2008). In several studies, it has been found that spelling training is particularly effective if a memory component is involved, as has been shown, for example, with visual dictation in Dutch (Bosman, Van Huygevoort et al., 2006; Hilte & Reitsma, 2006, 2008; Van Leerdam et al., 1998), visual imagery in Spanish (Gaintza & Goikoetxea, 2016), and the so-called cover-copy-compare strategy in English (Cates et al., 2007; Nies & Belfiore, 2006).

In a study conducted by Van Leerdam et al. (1998), 70 first graders were allocated randomly to one of five repeated spelling training conditions: visual dictation, word copying, oral spelling, word completion, or a reading control group. Independent of spelling ability, participants in the visual dictation group outperformed their peers in all other groups. Participants in the other spelling training conditions did not differ in their learning growth and only outperformed the reading control group. The authors concluded that in contrast to word copying, the requirement to spell words from memory increased the focus on orthographic details, which contributed to more specified lexical representations. Study material consisted of rule-based words, native irregularly spelled words, and loan words, but the authors did not differentiate between word types in their analyses.

Similarly, Hilte and Reitsma (2006, 2008) showed that previewing the correct word form before a spelling attempt led to better learning than normal dictation practice with the help of two within-subjects design studies. These two studies support the efficiency of visual dictation for rule-based words, irregular native words, and loan words. Third to sixth graders showed higher spelling accuracy for loan words trained with visual preview than after auditory dictation with feedback after mistakes (Hilte & Reitsma, 2006). The same was true for second graders who practiced rule-based words and native irregular words (Hilte & Reitsma, 2008). No differences were found between the word types, and untrained control words of various word types also improved from pre- to posttest. Transfer to untrained control words could not be allocated to the type of training because of the within-subjects design. The efficiency of visual dictation for rule-based spellings therefore remains inconclusive.

Bosman, Van Huygevoort et al. (2006) also found no differences between word types (rule-based words, native irregular words, and loan words) in terms of the efficiency of spelling words

from memory. In their study, second graders either received the correct form after a spelling mistake and had to spell the word again from memory or were only informed about the incorrectness of their spelling. Whereas good spellers learned equally efficiently in both training conditions, poor spellers showed quicker gains in spelling accuracy if they spelled the words from memory. In both training conditions and for participants with good and poor spelling abilities, transfer to spelling untrained words occurred. Transfer was best for loan words, followed by rule-based words, and was worst for irregular native words. The authors concluded that it seems easier to use analogy in order to spell untrained loan words correctly than to abstract a spelling rule. It can be concluded that visual dictation is efficient for teaching the spelling of rule-based words and loan words and that it transfers to untrained words. However, in this study, visual dictation was not contrasted with a word copying condition.

Superior learning by adding a memory aspect to a repeated spelling training in contrast to simple copying was reported by Gaintza and Goikoetxea (2016). Third and fifth graders practiced spelling irregular Spanish words in one of three conditions: self-correction, word copying, or imagery practice (in which the correct word form was previewed and was afterward written from memory with the nose in the air). These training conditions were contrasted with two control groups that practiced either reading or regular dictation without feedback. Although all training conditions outperformed the control groups directly after the training, this benefit was maintained over the long term only by the groups practicing with self-correction and imagery. The copying practicing group showed initial learning gains that were quickly lost without practice. The authors did not compare the groups directly and did not investigate differences between word types. In contrast to spelling words from memory, writing words with the nose in the air did not provide to a similar degree visual support from comparing top-down and bottom-up information during spelling, which might have covered the benefit of the memory aspect in imagery practice over self-correction.

The cover-copy-compare strategy and similar approaches are widely used in English spelling instruction, in which students have to focus on the word, cover it, spell it from memory, check, and self-correct (Westwood, 2014). This type of training appeared to be more efficient than copying words for third graders with spelling difficulties (Cates et al., 2007; Nies & Belfiore, 2006). These studies, however, were based on very small samples, and other studies that supported the efficiency of cover-copy-compare approaches only used a control group that spelled words without receiving feedback (Erion, Davenport, Rodax, Scholl, & Hardy, 2009; Jaspers et al., 2012).

This overview of the literature shows converging evidence of the benefits of spelling words from memory for learning to spell both rule-based words and loan words. Previously it was discussed that visual dictation fosters lexical learning especially and thus should be an efficient memorization strategy for irregular word spellings, such as for loan words (Hilte & Reitsma, 2006). It is not clear whether visual dictation is only efficient in teaching word-specific representations of trained rule-based words and loan words or whether it is also efficient for transferring knowledge to untrained words of those two word types by making use of analogy or by implicitly teaching spelling rules (Bosman, Van Huygevoort, et al., 2006; Hilte & Reitsma, 2008, 2011b). The studies mentioned above either were small, used inconsistent study material, did not compare different word types, or did not contrast the benefit of visual dictation practice with simple word copying. To evaluate the acquisition of spelling rules, transfer to untrained rule-based words also needs to be investigated.

More evidence is required from a larger sample of the efficiency of visual dictation over time in contrast to simple copying of words for trained rule-based words and loan words and its transfer to untrained rule-based words and loan words. Given the underlying shared representations of spelling and reading, it is easy to assume that spelling transfers to reading (Conrad, 2008; Martin-Chang et al., 2014; Shahar-Yames & Share, 2008). Most studies so far have not measured transfer to spelling untrained words and reading, which is highly relevant for the evaluation of

instructional efficiency (Conrad, 2008). This transfer gives an insight into the quality of lexical representations acquired during training, which is essential for possibilities of making use of analogy and for implicit spelling rule acquisition in order to show transfer to reading and spelling. Finally, it should be noted that most previous studies have not investigated the effects of spelling speed, which is a relevant constituent of processing automaticity, and therefore a relevant constituent of lexical quality (Perfetti, 1992).

The present study

In the present study, we investigated spelling accuracy and speed effects for rule-based words and loan words in a computerized repeated spelling training with two spelling feedback conditions. Growth during training after incorrectly spelling words was compared between two spelling feedback conditions: (a) visual dictation, in which the correct form was provided for 5 s and spelling from memory was subsequently required; and (b) word copying, in which the correct form just had to be copied. These training conditions were contrasted with a control condition, in which the participants only received feedback on correctness. Besides training effects, we also compared performance in consecutive sessions. Near transfer to reading accuracy and speed of trained words as well as far transfer to accuracy and speed of spelling and reading comparable untrained words were examined. Improvement in spelling the trained words was assessed during training. Near and far transfer were measured via pre- and posttest. The highest training effects as well as the highest near and far transfer effects to accuracy and speed of spelling and reading were assumed for groups that acquired the best qualified lexical representations for the trained words. The highest gains for both rule-based words and loan words were expected for participants in the visual dictation group, followed by the word copying group; the lowest gains were predicted for the control group. We also expected to find similar outcomes on the transfer measures. Those group differences were assumed to be stronger for loan words than for rule-based words because the use of a visual memorization strategy is more suitable for loan words derived from conventional orthography than for rule-based words.

Method

Design

Before the participants participated in a spelling training, reading of two comparable word lists (A and B) and spelling of a third comparable word list (C) were assessed at pretest. Next a computerized repeated spelling training of five sessions was conducted, with one session per day. The participants practiced spelling word list B. Each session, each word was practiced only once. Growth from the first to the fifth training session was under investigation. Therefore, only reading and not spelling of the trained word list was assessed at pretest. After the spelling training, at posttest, the participants were asked again to read word lists A and B as well as to spell word list C. From this, near transfer to reading trained words (word list B), far transfer to reading untrained words (word list A), and far transfer to spelling untrained words (word list C) were assessed. Pretest, posttest, and training sessions took place on different days. The sessions were conducted at schools during lecture times. Data were collected by the first author (a speech therapist with a master of arts in linguistics) and two undergraduate pedagogy students in their final year. The students were trained by the first author.

Participants

A total of 103 Dutch fifth and sixth graders from five different schools in two cities and a suburb in the southeastern regions of The Netherlands participated in this study. The socioeconomic status of these schools was diverse, with status scores ranging from -2.8 to 1.45 (Dutch average = 0 , min = -8.07 , max = 2.89) and rank scores ranging from 250 to $3,454$ (Dutch average = $1,773.5$, highest = 1 , lowest = $3,546$; Planbureau, 2016). Data from 12 participants were excluded because of incompleteness. Data from one participant were excluded because the child did not take the task seriously (i.e., filled out just letters instead of doing the task). Ultimately, data from 90 participants (44 females, 46 males) with a mean age of 11;25 years ($SD = 7$ months) were included in the analysis. Participants were randomly assigned to one of the two spelling feedback groups or the control group, equally distributed within each of the five classes. Parental consent for participation was obtained. Ethical approval was provided by the Ethics Committee of the Faculty of Social Sciences of our university (ECSW2016-0905-402). The children received a small gift after participating. Some participants indicated the use of additional home languages besides Dutch with their parents or siblings ($n = 27$), and teachers reported diagnosed dyslexia for eight children and other language-related or developmental problems for six children. These children were balanced across the training groups.

Materials

Standardized measures and questionnaires

Two standardized tests were administered prior to the training. A digit span task, taken from the Dutch translation of the Wechsler Intelligence Scale for Children (Kort et al., 2005), measured verbal memory capacities, and an isolated word reading task (the One-Minute-Test; Brus & Voeten, 1979) indicated general reading fluency. Furthermore, a questionnaire was used to evaluate the child's home language use. Overall, testing took about 15 min and was conducted with each child individually. In addition, teachers evaluated students' vocabulary on a scale indicating proficiency at five levels of the normal distribution (0%–20%, 20%–40%, 40%–60%, 60%–80%, and 80%–100%).

Spelling training

A computerized spelling training was developed with the software PsychoPy (Peirce, 2007) by using the programming language Python (Python Software Foundation, 2016). Participants listened to auditory stimuli from a headphone (Sennheiser HD 201) and had to type each word in a blue box on a gray screen. We used Dell Latitude E5450 laptops with a 13.2-inch screen and HP ProBook 6560b laptops with a 15.6-inch screen. Participants could listen to the auditory presentation unlimited times by clicking on a small speaker icon. To continue to the next item, the children had to press "Enter" on the keyboard. The "Enter" key was colored in red and marked by the written note "ok." Participants received different forms of feedback depending on their assignment to the feedback group (visual dictation, word copying) or the control group, as described below. Sessions took about 10–15 min and could not be paused in between. The training was conducted in groups of at most eight children with one laptop per participant. The first training session was preceded by four practice items including difficult letter combinations on the keyboard, such as apostrophe *s* and dieresis. The word order was random. The use of letter combinations was instructed by using different colors for each key. A memory note for the letter combinations was available during all sessions.

Visual dictation. Praise in form of a happy smiley face was provided after each correctly spelled word. After a mistake, the incorrect spelling was colored in red and the following auditory

feedback was provided: “This was not correct” (Dutch: *Dat was niet helemaal goed.*). Next the correct word form appeared on the screen for 5 s in 22-point MS Shell Dlg 2 font and the auditory stimulus was provided once more. After the correct word form disappeared, participants were asked to spell the word again from memory in a blue box below the box in which the correct spelling had been provided. After this learning phase, a happy smiley face followed correct spellings. Incorrect spellings were again colored in red and were accompanied by a sad smiley face. The correct word spelling appeared in a blue box on the screen above the incorrectly spelled words. Afterward the participants automatically continued with the next item.

Word copying. The same procedure was followed as described above for the visual dictation group. The only difference was in the feedback on incorrectly spelled words. The correct word form stayed visible on the screen while the participants were asked to spell the word again (by copying it from the written example).

Control group. As at the final feedback level for the feedback groups, incorrectly spelled words were lighted up in red and a sad smiley face appeared on the screen. No visual feedback was provided on the correct spellings of words, but if children continued to the next item without a sad smiley face, they knew that they had spelled the word correctly. The auditory stimuli were not presented again, and the correct written form was never provided.

Transfer to spelling untrained words

At pretest and posttest, each participant spelled word list C on a laptop. The procedure of the spelling training was followed, but without any feedback being provided. Practice items were provided at pretest. Words were presented in the same order at pre- and posttest.

Transfer to reading trained and untrained words

At pre- and posttest, each participant had to read aloud first the untrained word list A and next the trained word list B. Participants were instructed to read as correctly and as fast as possible all words per word list in a row. The assessment of both lists took about 5 min. Word order was stable at pre- and posttest.

Stimuli

Three comparable word lists (A, B, and C) were constructed (see [Supplementary Appendix A](#)). To control for spelling difficulty, each word list included the same number of words with clusters, words based on certain spelling rules (e.g., vowel length in open and closed syllables of multisyllabic words¹), and words with the same spelling irregularity due to foreign language origin (e.g., *th* for /t/ in *theater*; see Nunn, 1998, for further details). Each word list contained an equal number of bi- and trisyllabic words per word type. In this study, loan words were considered to be words originating from a different language with an incomplete adaptation to the Dutch orthography (Nunn, 1998). Item selection aimed at a low written lemma frequency based on the BasiLex corpus (Tellings, Hulsbosch, Vermeer, & Van den Bosch, 2014). The mean written lemma frequency was 202.23 ($SD = 217.35$, range = 6–975). The written lemma frequency, family

¹In closed syllables (final consonant), long vowels are represented by two graphemes (e.g., *boom* for /bɔ:m/, English: “tree”), and short vowels are represented by one grapheme (e.g., *bom* for /bɔm/, English: “bomb”). In open syllables (final vowel), long vowels are represented by only one grapheme. Vowel length is marked by vowel degemination or consonant doubling in multisyllabic words (e.g., plural derivation: *bomen* for /bɔ:mə(n)/, English: “trees”; *bommen* for /bɔmə(n)/, English: “bombs”).

size, geometric mean, and grapheme and phoneme length did not differ significantly between word lists and sublists of rule-based words, loan words, and bi- and trisyllabic words (one-way analyses of variance [ANOVAs]; all $F_s < 1$, $p_s \geq .46$, $r_s \leq .15$). Three of five teachers estimated that the meanings of most items were well known by 80%–100% of the target group.

Measures

Spelling measures

For spelling accuracy, the mean percentage of correct items was calculated for each measurement. If there were missing data, the percentage was corrected to the total number of words spelled per individual (max = four cases per individual). Two spelling speed measures in milliseconds were used to differentiate between the retrieval of lexical representations or spelling rules and the production of the word. Reaction Time 1 (RT1) represents the time between the end of the auditory stimulus and the first pressed key (retrieval). Reaction Time 2 (RT2) denotes the time between the first pressed key and pressing “Enter” to move to the next item (production). Because studies on spelling speed were not available, this distinction was aligned with studies measuring reading speed (e.g., De Jong & Share, 2007; Huemer et al., 2010; Thaler et al., 2004). For the analysis, the mean scores for all correctly spelled words were used per measurement per participant.

Reading measures

Reading accuracy was scored as the mean percentage of items read correctly per list. Words were noted as correct if their pronunciation corresponded to the grapheme pattern. If loan words were read with a direct grapheme–phoneme convergence, they were considered incorrect. Based on the ratings of two experimenters for 23 participants, an intraclass correlation of .91 and an interitem correlation of .83 were calculated. According to Green (2013), this indicates high interrater reliability. Reading speed represents the time in milliseconds from the beginning of the process of decoding the first word until the voice offset of reading the final word on the respective word list. This was measured with a stopwatch per word list including also incorrectly read words.

Data analysis

Using repeated measures ANOVAs, we compared growth on spelling the trained words from the first to the fifth training session between groups using time (five levels: Trainings 1–5) and word type (two levels: rule-based words, loan words) as within-subjects factors. Group (visual dictation, word copying, control group) functioned as a between-subjects factor. Similarly, we measured transfer to spelling untrained words by comparing the spelling performance on word list C prior to and after the spelling training for each word type. For this, the within-subjects factor of time was changed to two levels (pre- and posttest). Next, to investigate transfer to reading trained and untrained words, we compared reading performance prior to and after the training on word list B (trained in spelling) and word list A (not trained in spelling). Time (two levels: pre- and posttest) and word list (two levels: trained and untrained) were used as within-subjects factors. Group was added again as a between-subjects factor. If the assumption of sphericity was not met, degrees of freedom were corrected according to Greenhouse-Geisser estimates. Levene’s test for homogeneity of variance was significant for spelling accuracy of rule-based words at the fifth training session, $F(2, 87) = 4.40$, $p = .02$. Calculation and interpretation of effect sizes were based on Field (2009).

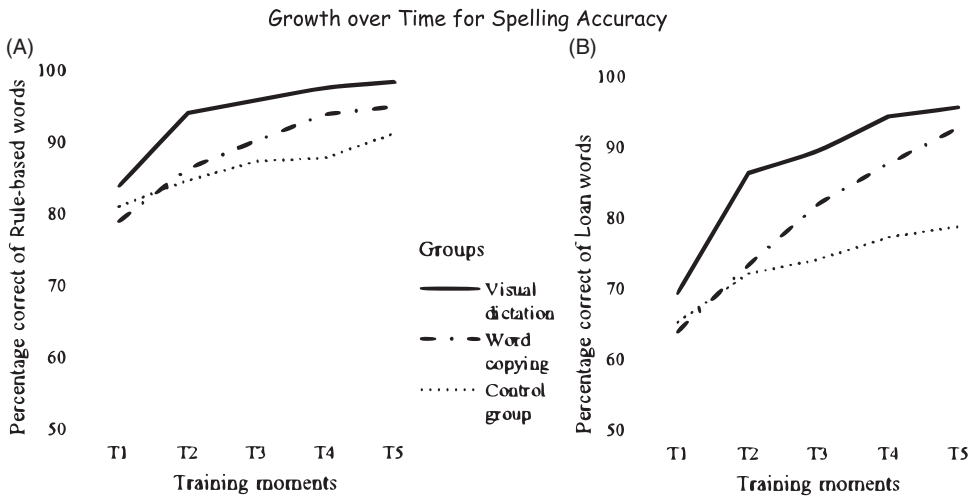


Figure 1. Mean percentages of correctly spelled words at Trainings 1–5 by groups and word type.

Results

The pretest, training and posttest sessions were spread over 13 days on average ($SD = 2.5$ days, range = 9–19 days). The duration of the data collection period did not differ significantly between groups (days between pre- and posttest, Training 1 and posttest, Training 1 and Training 5; Kruskal-Wallis Test, all $\chi^2(2) \leq 3.34$, $ps \geq .19$). The groups did not differ significantly in age, memory capacity and reading fluency, or vocabulary as rated by teachers: age, one-way ANOVA, $F(2, 87) = 0.82$, $p = .45$, $r = .14$; memory capacity and reading fluency, one-way ANOVAs, all $Fs \leq 2.19$, $ps \geq .12$, $rs \leq .22$; vocabulary, $\chi^2(4) = 5.15$, $p = .27$. An overview of the descriptive statistics by group is provided in [Supplementary Appendix B](#).

Data screening

Spelling accuracy was quite high prior to the training. Minimally 80% of the trained words were spelled correctly at the first training session by 37.80% of the participants, and minimally 80% of the untrained words were spelled correctly at pretest by 35.60% of the participants. Spelling speed measures showed large standard deviations and extreme scores (e.g., RT2 at the fifth training ranged from 15 ms to 357,018 ms), indicating possible data flaws. For the other variables, no outliers were observed.

We cleaned the spelling speed measures by removing outliers based on a trimmed mean (Field, 2009; Kyu Kwak & Hae Kim, 2017). After we removed all cases that deviated more than 3.29 SD (probability of occurring is .001 in a normal distribution), the mean for this restricted sample was used to identify all items from the unrestricted sample that deviated more than 3.29 SD from the mean at each measurement as outliers. For each training session 1.80%–3.60% and 3.20%–3.90% of the pre- and posttest data were removed as outliers.

Because accuracy scores and reaction times for spelling and reading deviated from the normal distribution (skewness and kurtosis divided by their standard errors extended were not higher than 2 or lower than -2), all variables were transformed to normal or close to normal for the analysis (Field, 2009; Tabachnik & Fidell, 2013). An overview of the transformations is provided in [Supplementary Appendix C](#).

Table 1. Repeated Measures ANOVA: Growth on Spelling Accuracy of Trained Words

Effect (<i>df</i>)	Trained rule-based words			Trained loan words		
	<i>F</i>	<i>p</i>	η_p^2	<i>F</i>	<i>p</i>	η_p^2
Time (4, 348)	65.59	<.001	.43	76.82	<.001	.47
Group (2, 87)	12.43	<.001	.22	13.13	<.001	.23
Time x Group (8, 348)	2.25	.02	.05	9.63	<.001	.18
Bonferroni corrected post hoc test		<i>p</i>	Cohen's <i>d</i>		<i>p</i>	Cohen's <i>d</i>
Visual dictation vs. word copying		.003	−0.45		.04	−0.33
Visual dictation vs. control		<.001	−0.63		<.001	−0.66
Word copying vs. control		.50	−0.18		.04	−0.33

Table 2. One-way ANOVA's: Comparison of Groups on Spelling Accuracy per Training Moment

Variable	<i>F</i> (2, 87)	<i>p</i>	<i>r</i>	Bonferroni corrected post hoc tests					
				Visual dictation vs. word copying		Visual dictation vs. control group		Word copying vs. control group	
				<i>p</i>	Cohen's <i>d</i>	<i>p</i>	Cohen's <i>d</i>	<i>p</i>	Cohen's <i>d</i>
Rule-based words									
Training 1	1.95	.15	.21	.18	−0.25	.46	−0.19	1.0	0.06
Training 2	10.23	<.001	.44	.002	−0.45	<.001	−0.55	1.0	−0.10
Training 3	8.30	.001	.40	.01	−0.39	.001	−0.51	1.0	−0.12
Training 4	10.86	<.001	.45	.08	−0.29	<.001	−0.60	.054	−0.31
Training 5	7.10	.001	.37	.06	−0.30	.001	−0.48	.51	−0.18
Loan words									
Training 1	1.01	.37	.15	.51	−0.18	.99	−0.13	1.0	0.05
Training 2	12.59	<.001	.47	<.001	−0.55	<.001	−0.58	1.0	−0.03
Training 3	7.89	.001	.39	.19	−0.25	<.001	−0.51	.12	−0.27
Training 4	17.72	<.001	.54	.07	−0.30	<.001	−0.76	.002	−0.46
Training 5	23.12	<.001	.59	.74	−0.15	<.001	−0.82	<.001	−0.67

Direct effects of the spelling training

Spelling accuracy of trained words

Figure 1 presents the mean percentages of correctly spelled rule-based words and loan words per group for each of the five training sessions. A significant interaction between time, group, and word type indicated small group differences in growth over time for rule-based words and loan words, $F(8, 348) = 2.15$, $p = .03$, $\eta_p^2 = .05$. The underlying interaction between time and group and the main effects of time and group were significant and large effects: Time \times Group interaction, $F(8, 348) = 8.49$, $p < .001$, $\eta_p^2 = .16$; time, $F(4, 348) = 125.31$, $p < .001$, $\eta_p^2 = .59$; group, $F(2, 87) = 15.21$, $p < .001$, $\eta_p^2 = .26$. Higher accuracy of rule-based words over time than loan words at each training session was indicated by a significant and large main effect of word type, $F(1, 87) = 88.98$, $p < .001$, $\eta_p^2 = .51$. Other interaction effects were not significant (all $F_s \leq 2.23$). To better understand the three-way interaction effect, we repeated the analysis for rule-based words and loan words separately.

The results of the repeated measures ANOVA for word type are presented in Table 1. For spelling accuracy of both rule-based words and loan words, growth over time differed significantly between groups. The effect was large for loan words and small for rule-based words. For rule-based words and loan words, Bonferroni corrected post hoc analyses revealed significantly higher growth for the visual dictation group compared to both the word copying group and the control group. The word copying group only outperformed the control group in growth for loan words. Those effect sizes varied from small to large.

To better interpret the significant interaction effect between time and group for rule-based words and loan words, we compared the groups' performance on spelling accuracy per training session with one-way ANOVAs. The results are provided in Table 2. At Training 1, the groups

Table 3. Mean Speed in ms for Spelling of the Trained Words

Variable	Visual dictation			Word copying			Control group		
	Total	Rule-based words	Loan words	Total	Rule-based words	Loan words	Total	Rule-based words	Loan words
RT1									
Training 1	1,867.18 (838.84)	1,876.56 (842.94)	1,855.96 (834.87)	1,939.96 (819.29)	2,001.28 (889.36)	1,864.71 (718.13)	1,909.25 (817.54)	1,930.72 (886.29)	1,882.52 (723.07)
Training 2	1,745.96 (681.53)	1,767.10 (699.84)	1,722.80 (660.83)	1,825.78 (677.30)	1,850.05 (688.28)	1,797.70 (664.06)	1,846.81 (761.24)	1,864.46 (763.91)	1,826.39 (758.52)
Training 3	1,739.79 (629.39)	1,749.99 (622.42)	1,728.90 (637.19)	1,754.15 (604.38)	1,765.91 (612.55)	1,740.97 (595.46)	1,777.86 (609.89)	1,771.14 (587.81)	1,785.90 (637.19)
Training 4	1,724.22 (612.64)	1,719.45 (593.24)	1,729.14 (630.61)	1,720.04 (553.37)	1,730.54 (563.11)	1,709.08 (543.35)	1,700.05 (594.46)	1,661.08 (537.06)	1,744.24 (651.26)
Training 5	1,694.47 (816.85)	1,719.99 (830.18)	1,668.55 (803.00)	1,742.66 (803.15)	1,753.02 (817.11)	1,731.99 (789.13)	1,881.25 (1,100.79)	1,909.14 (1,167.41)	1,848.96 (1,018.49)
RT2									
Training 1	3,979.83 (2,122.96)	4,112.08 (2,191.27)	3,823.09 (2,030.65)	4,193.83 (2,144.90)	4,396.04 (2,331.60)	3,943.27 (1,860.95)	4,192.99 (2,206.05)	4,392.42 (2,327.20)	3,948.18 (2,023.75)
Training 2	4,007.04 (2,083.72)	4,101.98 (2,098.54)	3,905.33 (2,065.02)	4,115.66 (2,106.47)	4,278.95 (2,232.60)	3,928.33 (1,937.45)	3,880.11 (2,056.18)	4,053.68 (2,176.41)	3,679.25 (1,890.25)
Training 3	3,949.92 (2,086.50)	4,194.17 (2,248.71)	3,690.73 (1,866.82)	4,035.04 (2,049.26)	4,165.58 (2,091.22)	3,892.76 (1,994.98)	3,785.08 (1,924.96)	3,892.94 (1,980.68)	3,658.72 (1,851.78)
Training 4	3,784.25 (1,876.20)	3,846.36 (1,944.15)	3,721.12 (1,804.10)	4,005.00 (2,001.69)	4,100.45 (1,966.52)	3,903.55 (2,033.40)	3,653.79 (1,811.21)	3,730.02 (1,855.36)	3,566.85 (1,757.48)
Training 5	3,671.54 (1,952.56)	3,723.30 (1,987.54)	3,618.27 (1,916.25)	3,771.57 (1,799.95)	3,927.85 (1,890.94)	3,612.44 (1,689.22)	3,612.70 (1,903.68)	3,753.92 (1,923.53)	3,451.05 (1,869.63)

Note. Standard deviations are provided within parentheses, n items = 40, n rule-based words = 20, n loan words = 20, RT1 = time before starting to type the word after auditory presentation, RT2 = time for typing the word.

did not differ significantly in their spelling accuracy of rule-based words and loan words, but significant differences were observed for Trainings 2–5, with medium to large effect sizes. For both types of words, participants in the visual dictation condition showed significantly higher spelling accuracy than participants in the word copying group and the control group already at Training 2 (large effects). In contrast to participants in the control group, participants in the word copying group caught up with the visual dictation condition at Training 4 for rule-based words and at Training 3 for loan words. Although participants in the word copying group never outperformed the control group on spelling accuracy of rule-based words, they did so for loan words from Training 4 onward with medium to large effect sizes, albeit two training sessions later than participants in the visual dictation group.

Spelling speed of trained words

Table 3 presents the spelling speed RT1 and RT2. All participants improved significantly over time in their spelling speed RT1 and RT2: RT1, $F(4, 348) = 11.44$, $p < .001$, $\eta_p^2 = .12$; RT2, $F(3.6, 310.2) = 12.93$, $p < .001$, $\eta_p^2 = .13$. For RT2, the main effect of word type was significant, $F(1, 87) = 83.10$, $p < .001$, $\eta_p^2 = .50$. These effect sizes were medium to large. Loan words were spelled significantly more quickly than rule-based words at all time points for RT2 (paired-samples t tests), all $t(89) \leq -2.87$, all $ps \leq .005$, $r = .29$. No other significant effects were found for the spelling speed measures (all $Fs \leq 3.39$).

Transfer effects of the spelling training

Transfer to spelling

Table 4 provides the spelling measures for untrained words.

Table 4 Mean Percentage Correct and Speed in ms for Spelling of the Untrained Words

Group and word type	Pretest			Posttest		
	Accuracy	RT1	RT2	Accuracy	RT1	RT2
Total	69.87 (16.52)	1,907.21 (746.36)	4,891.65 (2,839.81)	73.60 (15.14)	1,815.69 (731.72)	4,025.47 (2,113.83)
Rule-based words	76.67 (15.56)	1,902.11 (768.18)	5,014.59 (2,994.66)	78.11 (13.46)	1,765.43 (723.20)	4,103.78 (2,202.55)
Loan words	63.06 (20.26)	1,913.40 (719.26)	4,742.11 (2,632.89)	69.17 (19.04)	1,872.51 (737.43)	3,936.76 (2,005.80)
Visual dictation	74.45 (14.91)	1,938.08 (802.97)	4,701.98 (2,702.22)	77.21 (13.87)	1,812.94 (748.20)	3,996.38 (2,185.69)
Rule-based words	81.55 (13.10)	1,946.23 (833.34)	4,806.38 (2,851.19)	80.52 (13.18)	1,772.94 (778.17)	4,077.20 (2,291.40)
Loan words	67.24 (19.58)	1,927.90 (764.35)	4,574.34 (2,506.00)	74.14 (16.96)	1,856.63 (713.29)	3,908.13 (2,063.23)
Word copying	65.23 (17.15)	1,897.57 (728.50)	5,077.10 (2,940.38)	69.27 (15.77)	1,825.61 (667.20)	4,233.85 (2,070.41)
Rule-based words	71.33 (15.86)	1,900.26 (764.79)	5,215.70 (3,078.69)	74.33 (13.18)	1,774.21 (621.72)	4,325.78 (2,125.90)
Loan words	59.00 (21.27)	1,894.40 (684.37)	4,911.11 (2,760.94)	64.17 (20.81)	1,886.03 (713.12)	4,128.97 (2,002.90)
Control group	70.06 (16.63)	1,885.28 (702.60)	4,912.09 (2,871.90)	74.42 (15.09)	1,809.35 (771.29)	3,866.48 (2,068.46)
Rule-based words	77.26 (16.22)	1,859.70 (699.48)	5,041.93 (3,049.93)	79.52 (13.62)	1,750.34 (756.84)	3,931.40 (2,172.30)
Loan words	63.06 (19.73)	1,916.37 (706.04)	4,753.97 (2,632.46)	69.35 (18.43)	1,877.40 (783.04)	3,790.75 (1,940.18)

Note. Standard deviations are provided within parentheses, n items = 40, n rule-based words = 20, n loan words = 20, RT1 = time before starting to type the word after auditory presentation, RT2 = time for typing the word.

Spelling accuracy of untrained words. We found a significant interaction of medium effect size between time and word type, $F(1, 87) = 10.23$, $p = .002$, $\eta_p^2 = .11$. Spelling accuracy of rule-based words was significantly greater than that of loan words at both pretest and posttest (paired-samples t tests): pretest, $t(89) = -9.03$, $p < .001$, $r = .69$; posttest, $t(89) = -6.04$, $p < .001$, $r = .54$. Accuracy of loan words increased significantly from pre- to posttest (paired-samples t test), $t(89) = -6.51$, $p < .001$, $r = .57$. However, accuracy of rule-based words did not improve significantly over time (paired-samples t test), $t(89) = -1.14$, $p = .26$, $r = .12$, thus explaining the interaction. The main effects of time and word type were significant, with large effect sizes: time, $F(1, 87) = 25.62$, $p < .001$, $\eta_p^2 = .23$; word type, $F(1, 87) = 74.48$, $p < .001$, $\eta_p^2 = .46$. Other main and interaction effects were not significant (all $F_s \leq 1.51$).

Spelling speed of untrained words. For RT1, the interaction between time and word type was significant, but a small effect, $F(1, 87) = 4.81$, $p = .03$, $\eta_p^2 = .05$. Spelling speed RT1 of rule-based words and loan words did not differ significantly at pretest (paired-samples t test), $t(89) = 1.04$, $p = .30$, $r = .11$. However, RT1 of untrained rule-based words was significantly faster than that of loan words after the training (paired-samples t test), $t(89) = 3.77$, $p < .001$, $r = .37$. Spelling speed RT1 improved significantly over time for rule-based words but only marginally for loan words (paired-samples t test): rule-based words, $t(89) = 3.8$, $p < .001$, $r = .37$; loan words, $t(89) = 1.9$, $p = .06$, $r = .20$. The underlying main effects of time and word type were significant, with medium effect sizes: time, $F(1, 87) = 11.14$, $p = .001$, $\eta_p^2 = .11$; word type, $F(1, 87) = 11.02$, $p < .01$, $\eta_p^2 = .11$. Other main and interaction effects were not significant (all $F_s \leq 1$).

For RT2, the main effects of time and word type were significant: time, $F(1, 87) = 124.11$, $p < .001$, $\eta_p^2 = .59$, large effect; word type, $F(1, 87) = 7.23$, $p = .009$, $\eta_p^2 = .08$, medium effect. Other significant effects were not found (all $F_s \leq 1.77$). Although at pretest the spelling speed RT2 of the two word types did not differ significantly, untrained loan words were spelled significantly faster than rule-based words after the training (paired-samples t tests): pretest,

Table 5. Mean Percentage Correct and Speed in ms for Reading of the Trained and Untrained Words

Group	Pretest				Posttest			
	Trained		Untrained		Trained		Untrained	
	Accuracy	Speed	Accuracy	Speed	Accuracy	Speed	Accuracy	Speed
Total	95.36 (3.47)	35,552.92 (9,953.06)	94.03 (5.19)	37,672.25 (11,181.97)	97.69 (2.13)	26,685.46 (5,439.07)	94.41 (4.09)	32,121.57 (8,898.45)
Visual dictation	96.12 (2.55)	33,929.36 (10,709.44)	94.57 (4.82)	35,188.33 (9,741.14)	97.67 (2.20)	25,786.24 (6,430.35)	95.34 (3.52)	30,725.89 (9,636.11)
Word copying	95.33 (3.33)	38,057.70 (9,721.43)	93.00 (4.75)	40,545.35 (12,522.96)	98.00 (2.01)	27,100.68 (4,658.22)	93.75 (4.19)	34,298.35 (9,104.20)
Control group	94.68 (4.22)	34,647.76 (9,263.77)	94.51 (5.90)	37,215.50 (10,783.33)	97.42 (2.19)	27,124.84 (5,200.22)	94.19 (4.44)	31,320.65 (7,799.71)

Note. Standard deviations are provided within parentheses.

$t(89) = -1.76$, $p = .08$, $r = .18$; posttest, $t(89) = -2.33$, $p = .02$, $r = .24$. Significant growth over time was found for rule-based words as well as for loan words (paired-samples t tests): rule-based words, $t(89) = 9.69$, $p < .001$, $r = .72$; loan words, $t(89) = 8.58$, $p < .001$, $r = .67$.

Transfer to reading

An overview of the pre- and posttest measures for reading trained and untrained words is presented in Table 5.

Reading accuracy of trained and untrained words. We found a significant and large interaction effect between time and word list, $F(1, 87) = 28.37$, $p < .001$, $\eta_p^2 = .25$. Accuracy of the trained and untrained words did not differ significantly at pretest, but trained words were read significantly more accurately than untrained words at posttest (paired-samples t tests): pretest, $t(89) = 1.46$, $p = .15$, $r = .15$; posttest, $t(89) = 7.51$, $p < .001$, $r = .62$. The participants improved significantly over time in reading accuracy for the trained word list B but not for the untrained word list A (paired-samples t tests): trained word list B, $t(89) = 6.32$, $p < .001$, $r = .56$; untrained word list A, $t(89) = -0.17$, $p = .87$, $r = .02$. The main effects of time and word list were significant, with large effect sizes: time, $F(1, 87) = 17.97$, $p < .001$, $\eta_p^2 = .17$; word list, $F(1, 87) = 29.50$, $p < .001$, $\eta_p^2 = .25$. Other effects were not significant (all $F_s \leq 2.7$).

Reading speed of trained and untrained words.. The interaction between time, group, and word list was significant and of medium effect size, $F(2, 87) = 3.55$, $p = .03$, $\eta_p^2 = .08$. Bonferroni corrected post hoc tests did not reveal any group differences in growth over time for reading speed of trained and untrained words (all $p_s \geq .13$). The interaction between time and word list was significant and of large effect size, $F(1, 87) = 75.83$, $p < .001$, $\eta_p^2 = .47$. Reading speed was significantly faster for the trained word list B than for the untrained word list A at pretest and posttest (paired-samples t tests): pretest, $t(89) = 4.34$, $p < .001$, $r = .42$; posttest, $t(89) = 12.39$, $p < .001$, $r = .80$. Reading speed improved significantly over time for the trained words and untrained words (paired-samples t tests): trained words, $t(89) = 19.17$, $p < .001$, $r = .90$; untrained words, $t(89) = 12.43$, $p < .001$, $r = .80$. With respect to the three-way interaction, group differences could be covered by the quicker spelling for the trained word list at pre- and posttest. The main effects of time and word list were significant and large: time, $F(1, 87) = 402.14$, $p < .001$, $\eta_p^2 = .82$; word list, $F(1, 87) = 124.97$, $p < .001$, $\eta_p^2 = .59$. Other interactions were not significant (all $F_s \leq 1.09$).

Discussion

This study investigated spelling accuracy and speed effects in a computerized repeated spelling training with two spelling feedback conditions. The efficiency of briefly presenting the correct

word form after spelling mistakes over and above word copying was examined for learning to spell Dutch rule-based words and loan words. After a spelling mistake, participants in the two feedback groups received feedback either in the form of visual dictation, in which the participants had to spell the word again from memory after a brief presentation of the correct form, or in the form of word copying, in which the correct form just had to be copied. This was contrasted to a control condition in which the participants only received feedback on accuracy. Direct training effects for each word type were compared between the groups. Near transfer to reading the trained words, far transfer to spelling comparable untrained rule-based words and loan words, as well as far transfer to reading of another set of comparable untrained words were examined in terms of gains in accuracy and speed from pre- to posttest.

First direct training effects are discussed. All groups increased in spelling accuracy and speed, but group differences were only identified in spelling accuracy. As expected, visual dictation was most efficient for learning to spell rule-based words and loan words; the word copying group only outperformed the control group on loan words, not on rule-based words. Word copying is also a useful way of learning to spell rule-based words, and especially loan words, because the word copying group caught up rather quickly with the visual dictation group on both word types, in contrast to the control group. It can be concluded that visual dictation was more efficient than word copying for learning to spell rule-based words and loan words, which complements the findings from previous research (e.g., Bosman, Van Huygevoort et al., 2006; Hilte & Reitsma, 2006, 2008). As the authors of earlier research concluded, spelling from memory increases the focus on orthographic details (e.g., Hilte & Reitsma, 2006, 2008; Van Leerdam et al., 1998). Visual dictations leads to a quicker implementation of specified lexical representations than word copying, because with copying more repetitions are required to reach the same accuracy level for both word types.

Although visual dictation was similarly efficient for rule-based words and loan words, the word copying group only outperformed the control group on loan words, even if those groups no longer differed by the end of the training on either word type. On the one hand, the high initial spelling ability for rule-based words might have covered group differences. On the other hand, the control group might have benefitted more for rule-based words than for loan words from the provided feedback on accuracy because rule-based words deviate less from the conventional orthography. An alternative explanation might have to do with an unconscious application of a regularized reading strategy during word copying (Bosman, Van Hell et al., 2006; Elbro & De Jong, 2017; Hilte & Reitsma, 2006). Being provided with the correct word form as feedback could lead to reading the correct word form in a regularized manner, which helps to remember loan word spelling, whereas this strategy is not applicable to rule-based words.

Next far transfer to spelling untrained comparable rule-based words and loan words is considered. All participants improved significantly over time in spelling accuracy and spelling speed. However, no group differences were found. It is interesting that transfer differed between word types. Transfer to spelling accuracy occurred for loan words, while rule-based words increased in spelling speed RT1 (time between the end of the auditory stimulus and the first pressed key). For both word types an increase in spelling speed RT2 (time between the first pressed key and the pressing of “Enter”) was found. It seems that the participants were only able to use their acquired knowledge during training for analogy spelling in order to spell comparable untrained loan words more accurately (e.g., Tucker et al., 2016), but they did not implicitly acquire a spelling rule from the training (Hilte & Reitsma, 2008, 2011b). The increase in spelling speed for rule-based words might indicate that words for which a spelling rule had already been acquired were spelled with higher automaticity (Perfetti, 1992, 2017). The reason why no increase in spelling speed was noted for loan words might be related to the higher difficulty level of this word type (Arndt & Foorman, 2010; Keuning & Verhoeven, 2008). An increase in spelling speed first requires a high specificity of the lexical representation, which increases in redundancy in order to automatize

access (Perfetti, 1992, 2017). An increase in spelling speed for already correctly spelled loan words at pretest was probably covered by slow spelling of newly acquired loan words at posttest.

The findings on transfer to comparable untrained words are partially in line with earlier research in which transfer to loan words was higher than to rule-based words (Bosman, Van Huygevoort et al., 2006). Bosman, Van Huygevoort, et al. (2006) concluded that analogy spelling is easier than spelling rule abstraction. In contrast to an earlier study, repeated spelling of rule-based words in this study did not lead to higher spelling accuracy of comparable untrained rule-based words (Hilte & Reitsma, 2011b). Future research should consider a larger number of examples per spelling rule in order to trigger implicit spelling rule acquisition or explicit spelling rule explanation (Hilte & Reitsma, 2008, 2011b). Still, the transfer effect for loan words found in this study should be considered with caution because the attention of the participants to comparable loan word spellings in their daily environment could have been increased.

With respect to transfer to reading trained and untrained words, all participants improved in their reading speed of trained and untrained words, but reading accuracy increased only for trained words. Even if direct training effects differed between groups, the near and far transfer effects to reading did not. Because reading accuracy only increased for trained words, we may conclude that this was caused by repeated spelling practice of those words. Improvements in reading speed are difficult to interpret because the trained words were read more quickly than the untrained words at pre- and posttest. Those effects might have been caused simply by repetition and may not clearly indicate transfer. No group differences on the transfer effect to reading were visible, probably because reading is easier than spelling words and because all participants repeatedly practiced the spelling of words, which is an efficient training method itself (Shahar-Yames & Share, 2008). Transfer from spelling to reading was also found in previous studies (Conrad, 2008; Kohnen, Nickels, & Coltheart, 2010; Ouellette, 2010; Shahar-Yames & Share, 2008). Because the feedback provided in our study also included reading of the target words, those results cannot provide evidence for the discussion of shared underlying lexical representations of reading and spelling (e.g., Coenen, Van Bon, & Schreuder, 1998; Hepner, McCloskey, & Rapp, 2017).

Some limitations of this study should be considered for the interpretation of the results and for future investigations. First, the heterogeneity of the sample and the high initial spelling ability might have covered some group differences. The study should be replicated with more difficult words or with a younger target group. Furthermore, the results should be compared between children with and without learning difficulties. Second, it should be noted that the difficulty level of the word types differed even after we controlled several linguistic variables (Arndt & Foorman, 2010; Keuning & Verhoeven, 2008). In future research, item selection should be based on a pilot, which was difficult to conduct in this study because of the need for three comparable word lists. Third, we checked the familiarity of the children with the stimuli by asking teachers to rate the children's knowledge of the meaning of each word. In future studies, children's knowledge of the meaning of items should be used as control measure, because not having been familiar with the meaning of a word may have influenced the spelling performance (Hilte & Reitsma, 2011a). Finally, future investigations should also consider follow-up tests to provide information on retention of the knowledge.

Conclusion

This study showed that briefly presenting the correct word form after a spelling mistake contributes to the efficiency of a repeated spelling training of difficult-to-spell words. In contrast to word copying or feedback on the accuracy of a spelling attempt, fewer repetitions were required in order to increase the spelling accuracy of Dutch rule-based words and loan words. Although word copying is also a useful method of teaching spelling, the need to spell words from memory

increased the focus on orthographic details and therefore led earlier to more specified lexical representations for both types of words. These results may be applicable not only to Dutch but also to other languages with spelling inconsistencies (Caravolas, 2006). Also, the results can be used to help children with spelling problems, as it has been shown that methods that are effective for children without spelling problems are also beneficial to children with spelling problems (Cordewener, Bosman, & Verhoeven, 2015). Because irregular word spellings and spelling rules may not be acquired during repeated reading of words, or may be acquired much more slowly, explicit spelling instruction is highly relevant, especially in languages with less consistent orthographies (Graham & Santangelo, 2014; Westwood, 2014). Lexical representations acquired during spelling instruction may also be more likely to transfer to reading words than vice versa (Conrad, 2008; Martin-Chang et al., 2014; Shahar-Yames & Share, 2008). Aligned with this, the results of this study showed that repeated spelling of words quickly led to the implementation of lexical representations of trained rule-based words, improved the reading accuracy of trained words, as well as improved the spelling accuracy of similar untrained loan words.

Funding

This work was supported by The Netherlands Initiative for Education Research (National Regieorgaan Onderwijs onderzoek) under Grant NWO 405-15-540-079.

References

- Abbott, R. D., Berninger, V. W., & Fayol, M. (2010). Longitudinal relationships of levels of language in writing and between writing and reading in grades 1 to 7. *Journal of Educational Psychology*, 102(2), 281–298. doi:10.1037/a0019318
- Apel, K. (2011). What is orthographic knowledge? *Language, Speech, and Hearing Services in Schools*, 42, 592–603. doi:10.1044/0161-1461(2011/10-0085)
- Arndt, E. J., & Foorman, B. R. (2010). Second graders as spellers: What types of errors are they making? *Assessment for Effective Intervention*, 36(1), 57–67. doi:10.1177/1534508410380135
- Berends, I. E., & Reitsma, P. (2006). Remediation of fluency: Word specific or generalized training. *Reading and Writing: An Interdisciplinary Journal*, 19, 221–234. doi:10.1007/s11145-005-5259-3
- Bhide, A. (2018). Copying helps novice learners build orthographic knowledge: Methods for teaching Devanagari akshara. *Reading and Writing: An Interdisciplinary Journal*, 31, 1–33. doi:10.1007/s11145-017-9767-8
- Bosman, A. M. T., De Graaff, S., & Gijzel, M. A. R. (2006). Double Dutch: The Dutch spelling system and learning to spell in Dutch. In R. M. Joshi & P. G. Aaron (Eds.), *Handbook of orthography and literacy* (pp. 135–150). Mahwah, NJ: Lawrence Erlbaum Associates.
- Bosman, A. M. T., Van Hell, J. G., & Verhoeven, L. (2006). Learning the spelling of strange words in Dutch benefits from regularized reading. *Journal of Educational Psychology*, 98(4), 879–890. doi:10.1037/0022-0663.98.4.879
- Bosman, A. M. T., Van Huygevoort, M., & Verhoeven, L. (2006). Spelling feedback in an IT-learning environment: Issues of proficiency, training efficiency, and transfer. *International Journal of Educational Research*, 45(6), 341–361. doi:10.1016/j.ijer.2007.01.001
- Bosman, A. M. T., & Van Leerdam, M. (1993). Aanvankelijk spellen: De dominantie van de verklankende spelwijze en de geringe effectiviteit van lezen als spellingsinstructie-methode [Beginning spelling: Prevalence of the phonological strategy in spelling and the scant effectivity of reading as a spelling instruction method]. *Pedagogische Studiën*, 70(1), 28–45.
- Bosse, M., Chaves, N., Largy, P., & Valdois, S. (2015). Orthographic learning during reading: The role of whole-word visual processing. *Journal of Research in Reading*, 38(1), 141–158. doi:10.1111/j.1467-9817.2012.01551.x
- Bosse, M. L., Valdois, S., & Tainturier, M. J. (2003). Analogy without priming in early spelling development. *Reading and Writing: An Interdisciplinary Journal*, 16(7), 693–716. doi:10.1023/A:1025883815395
- Brus, B. T., & Voeten, M. J. (1979). *Eén-Minut-Test, vorm A en B. Verantwoording en handleiding [One-Minute-Test, form A and B. Justification and manual]* (2nd ed.). Nijmegen and Lisse, The Netherlands: Berkhout Testmateriaal, Swets & Zeitlinger.
- Caravolas, M. (2006). Learning to spell in different languages: How orthographic variables might affect early literacy. In R. M. Joshi & P. G. Aaron (Eds.), *Handbook of orthography and literacy* (pp. 497–511). Mahwah, NJ: Lawrence Erlbaum Associates.

- Cates, G. L., Dunne, M., Erkfritz, K. N., Kivisto, A., Lee, N., & Wierzbicki, J. (2007). Differential effects of two spelling procedures on acquisition, maintenance and adaption to reading. *Journal of Behavioral Education*, 16, 71–82. doi:10.1007/s10864-006-9019-5
- Coenen, M., Van Bon, W., & Schreuder, R. (1998). The effect of reading and spelling practice on reading skill. In P. Reitsma & L. Verhoeven (Eds.), *Problems and interventions in literacy development* (pp. 321–334). Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Conrad, N.J. (2008). From reading to spelling and spelling to reading: Transfer goes both ways. *Journal of Educational Psychology*, 100(4), 869–878. doi:10.1037/a0012544
- Cordewener, K., Bosman, A., & Verhoeven, L. (2015). Implicit and explicit instruction: The case of spelling acquisition. *Written Language & Literacy*, 18(1), 121–152. doi:10.1075/wll.18.1.06cor
- Critten, S., Sheriston, L., & Mann, F. (2016). Young children's spelling representations and spelling strategies. *Learning and Instruction*, 46, 34–44. doi:10.1016/j.learninstruc.2016.09.001
- Deacon, S. H., Conrad, N., & Pacton, S. (2008). A statistical learning perspective on children's learning about graphotactic and morphological regularities in spelling. *Canadian Psychology*, 49(2), 118–124. doi:10.1037/0708-5591.49.2.118
- De Jong, P. F., & Share, D. L. (2007). Orthographic learning during oral and silent reading. *Scientific Studies of Reading*, 11(1), 55–71. doi:10.1080/10888430709336634
- Ehri, L. C. (2017). Orthographic mapping and literacy development revisited. In K. Cain, D. L. Compton, & R. K. Parrila (Eds.), *Theories of reading development* (pp. 127–145). Amsterdam, The Netherlands: John Benjamins Publishing Company.
- Elbro, C., & De Jong, P. F. (2017). Orthographic learning is verbal learning: The role of spelling pronunciations. In K. Cain, D. L. Compton, & R. K. Parrila (Eds.), *Theories of reading development* (pp. 169–189). Amsterdam, The Netherlands: John Benjamins Publishing Company.
- Erion, J., Davenport, C., Rodax, N., Scholl, B., & Hardy, J. (2009). Cover-Copy-Compare and spelling: One versus three repetitions. *Journal of Behavioral Education*, 18, 319–330. doi:10.1007/s10864-009-9095-4
- Field, A. (2009). *Discovering statistics using SPSS (and sex and drugs and rock 'n' roll)* (3rd ed.). London, UK: Sage Publications.
- Gaintza, Z., & Goikoetxea, E. (2016). Spelling instruction in Spanish: A comparison of self-correction, visual imagery, and copying. *Journal of Research in Reading*, 39(4), 428–447. doi:10.1111/1467-9817.12055
- Graham, S., & Santangelo, T. (2014). Does spelling instruction make students better spellers, readers, and writers? A meta-analytic review. *Reading and Writing: An Interdisciplinary Journal*, 27, 1703–1743. doi:10.1007/s11145-014-9517-0
- Green, R. (2013). *Statistical analyses for language testers*. Basingstoke, UK: Palgrave Macmillan.
- Hepner, C., McCloskey, M., & Rapp, B. (2017). Do reading and spelling share orthographic representations? Evidence from developmental dysgraphia. *Cognitive Neuropsychology*, 34(3–4), 119–143. doi:10.1080/02643294.2017.1375904
- Hilte, M., & Reitsma, P. (2006). Spelling pronunciation and visual preview both facilitate learning to spell irregular words. *Annals of Dyslexia*, 56(2), 301–318. doi:10.1007/s11881-006-0013-3
- Hilte, M., & Reitsma, P. (2008). What type of computer-assisted exercise supports young less skilled spellers in resolving problems in open and closed syllable words? *Annals of Dyslexia*, 58(2), 97–114. doi:10.1007/s11881-008-0019-0
- Hilte, M., & Reitsma, P. (2011a). Activating the meaning of a word facilitates the integration of orthography: Evidence from spelling exercises in beginning spellers. *Journal of Research in Reading*, 34(3), 333–345. doi:10.1111/j.1467-9817.2010.01442.x
- Hilte, M., & Reitsma, P. (2011b). Effects of explicit rules in learning to spell open- and closed- syllable words. *Learning and Instruction*, 21(1), 34–45. doi:10.1016/j.learninstruc.2009.10.002
- Huemer, S., Aro, M., Landerl, K., & Lyytinen, H. (2010). Repeated reading of syllables among Finnish-speaking children with poor reading skills. *Scientific Studies of Reading*, 14(4), 317–340. doi:10.1080/10888430903150659
- Jaspers, K. E., Williams, R. L., Skinner, C. H., Cihak, D., McCallum, R. S., & Ciancio, D. J. (2012). How and to what extent do two cover, copy, and compare spelling interventions contribute to spelling, word recognition, and vocabulary development? *Journal of Behavioral Education*, 21, 80–98. doi:10.1007/s10864-011-9137-6
- Johnson, A. C., Wilson, J., & Roscoe, R. D. (2017). College student perceptions of writing errors, text quality, and author characteristics. *Assessing Writing*, 34, 72–87. doi:10.1016/j.asw.2017.10.002
- Joshi, R. M., & Aaron, P. G. (2006). *Handbook of orthography and literacy*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Kemp, N., & Bryant, P. (2003). Do bees buzz? Rule-based and frequency-based knowledge in learning to spell plural-s. *Child Development*, 74(1), 63–74. doi:10.1111/1467-8624.00521
- Keuning, J., & Verhoeven, L. (2008). Spelling development throughout the elementary grades: The Dutch case. *Learning and Individual Differences*, 18(4), 459–470. doi:10.1016/j.lindif.2007.12.001
- Kohnen, S., Nickels, L., & Coltheart, M. (2010). Skill generalisation in teaching spelling to children with learning difficulties. *Australian Journal of Learning Difficulties*, 15(2), 115–129. doi:10.1080/19404158.2010.502588

- Kort, W., Schittekatte, M., Dekker, P.H., Verhaeghe, P., Compaan, E.L., Bosmans, M., & Vermeir, G. (2005). *WISC-IIIINL Wechsler Intelligence Scale for Children. David Wechsler. Derde Editie NL. Handleiding en Verantwoording* [3rd ed. Manual and justification]. Amsterdam, The Netherlands: Harcourt Test Publishers, NIP Dienstencentrum.
- Kyu Kwak, S., & Hae Kim, J. (2017). Statistical data preparation: Management of missing values and outliers. *The Korean Society of Anesthesiology*, 70(4), 407. doi:10.4097/kjae.2017.70.4.407
- Levy, B. (2001). Moving the bottom: Improving reading fluency. In M. Wolf (Ed.), *Dyslexia, fluency, and the brain* (pp. 357–379). Timonium, MD: York Press.
- Marinelli, C.V., Romani, C., Burani, C., & Zoccolotti, P. (2015). Spelling acquisition in English and Italian: A cross-linguistic study. *Frontiers in Psychology*, 6(1843), 1–13. doi:10.3389/fpsyg.2015.01843
- Martin-Chang, S., Quelette, G., & Madden, M. (2014). Does poor spelling equate to slow reading? The relationship between reading, spelling, and orthographic quality. *Reading and Writing: An Interdisciplinary Journal*, 27(8), 1485–1505. doi:10.1007/s11145-014-9502-7
- Nies, K. A., & Belfiore, P. J. (2006). Enhancing spelling performance in students with learning disabilities. *Journal of Behavioral Education*, 15, 163–170. doi:10.1007/s10864-006-9017-7
- Nunn, A. M. (1998). *Dutch orthography: A systematic investigation of the spelling of Dutch words*. The Hague, The Netherlands: Holland Academic Graphics.
- Pan, S. C., Rubin, B. R., & Rickard, T. C. (2015). Does testing with feedback improve adult spelling skills relative to copying and reading? *Journal of Experimental Psychology: Applied*, 21(4), 356–369. doi:10.1037/xap0000062
- Peirce, J. W. (2007). PsychoPy – Psychophysics software in Python. *Journal of Neuroscience Methods*, 162(1–2), 8–13. doi:10.1016/j.jneumeth.2006.11.017
- Perfetti, C. A. (1992). The representation problem in reading acquisition. In P. B. Gough, L. E. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 145–174). Hillsdale, NJ: Erlbaum.
- Perfetti, C. (2017). Lexical quality revisited. In E. Segers & P. Van den Broek (Eds.), *Developmental perspectives in written language and literacy: In honor of Ludo Verhoeven* (pp. 51–67). Amsterdam, The Netherlands/Philadelphia, PA: John Benjamins Publishing Company.
- Planbureau, S. E. (2016). *Socialeconomische status* [Socio-economic status]. Retrieved from http://www.scp.nl/Formulieren/Statusscores_opvragen
- Python Software Foundation. (2016) *Python language reference* (Version 3.6.0). Available at <http://www.python.org>
- Ouellette, G. (2010). Orthographic learning in learning to spell: The roles of semantics and type of practice. *Journal of Experimental Child Psychology*, 107, 50–58. doi:10.1016/j.jecp.2010.04.009
- Sankoff, G. (2006). Linguistic outcomes of language contact. In J. K. Chambers, P. Trudgill, & N. Schilling-Estes (Eds.), *The handbook of language variation and change* (pp. 638–668). Malden, MA: Blackwell Publishing.
- Shahar-Yames, D., & Share, D. L. (2008). Spelling as a self-teaching mechanism in orthographic learning. *Journal of Research in Reading*, 31(1), 22–39. doi:10.1111/j.1467-9817.2007.00359.x
- Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition*, 55(2), 151–218. doi:10.1016/0010-0277(94)00645-2
- Share, D. L. (2004). Orthographic learning at a glance: On the time course and developmental onset of self-teaching. *Journal of Experimental Child Psychology*, 87(4), 267–298. doi:10.1016/j.jecp.2004.01.001
- Sharp, A. C., Sinatra, G. M., & Reynolds, R. E. (2008). The development of children's orthographic knowledge: A microgenetic perspective. *Reading Research Quarterly*, 43(3), 206–226. doi:10.1598/RRQ.43.3.1
- Steffler, D. (2001). Implicit cognition and spelling development. *Developmental Review*, 21(2), 168–204. doi:10.1006/drev.2000.0517
- Tabachnik, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston, MA: Pearson.
- Tellings, A., Hulsbosch, M., Vermeer, A., & Van den Bosch, A. (2014). BasiLex: An 11.5 million words corpus of Dutch texts written for children. *Computational Linguistics in the Netherlands Journal*, 4, 191–208.
- Thaler, V., Ebner, E. M., Wimmer, H., & Landerl, K. (2004). Training reading fluency in dysfluent readers with high reading accuracy: Word specific effects but low transfer to untrained words. *Annals of Dyslexia*, 54(1), 89–113. doi:10.1007/s11881-004-0005-0
- Tucker, R., Castles, A., Laroche, A., & Deacon, S. H. (2016). The nature of orthographic learning in self-teaching: Testing the extent of transfer. *Journal of Experimental Child Psychology*, 145, 79–94. doi:10.1016/j.jecp.2015.12.007
- Van Gorp, K., Segers, E., & Verhoeven, L. (2017). The role of feedback and differences between good and poor decoders in a repeated word reading paradigm in first grade. *Annals of Dyslexia*, 67(1), 1–25. doi:10.1007/s11881-016-0129-z
- Van Leerdam, M., Bosman, A. M. T., & Van Orden, G.C. (1998). The ecology of spelling instruction: Effective training in first grade. In P. Reitsma & L. Verhoeven (Eds.), *Problems and interventions in literacy development* (pp. 307–320). Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Westwood, P. (2014). *Teaching spelling: Exploring common sense strategies and best practices*. Oxfordshire, UK/New York, NY: Routledge.